Variable Renewable Energy (VRE) Integration
Lessons Learned from Hawaii

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ASIA CLEAN ENERGY FORUM, REGIONAL SESSION
PACIFIC ENERGY TRANSITION CHALLENGES, OPPORTUNITIES, AND WAY FORWARD

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Hawaiʻi’s Electric Systems – State: ~35% Renewable Energy (2023)

4 Electric Utilities; 6 Separate Grids; % Renewable Energy

**Kauaʻi Island Utility Cooperative** – 60% RE
System Peak: 80 MW
125 MW PV* / 7 MW Biomass / 16 MW Hydro* / 260 MWh BESS
Installed PV: 156% of Sys. Peak

*West Kauai Energy Project (Approved)
Hydro 4 MW
PV 35 MWac/56 MWdc
+ 35 MW/70 MWh BESS
20 MW Pumped Hydro

**Hawaiian Electric** – 29.6% RE
System Peak: 1,216 MW
916 MW PV* / 123 MW Wind / 69 MW WTE / 168 MW Biofuel / 300 MWh BESS*
Installed PV & Wind: 85% of Sys. Peak

* 143.5 MW PV + 1,266 MWh BESS (Approved)
12 MW / 12 MWh BESS (Pending Approval)

**Maui Electric** – 29.6% RE
Maui System Peak: 206 MW
148 MW PV* / 72 MW Wind / 24 MWh BESS
Installed PV & Wind:
107% of Sys. Peak
Lanaʻi System Peak: 5.1 MW
2.9 MW PV* (57% of Sys. Peak)
Molokaʻi System Peak: 5.6 MW
2.7 MW PV / 2 MW BESS (48% of Sys. Peak)

**Maui**
* 75 MW PV + 300 MWh BESS (Approved)
40 MW PV + 160 MWh BESS (Pending Approval)

**Hawaii Electric Light** – 52.1% RE
System Peak: 191 MW
161 MW PV* / 34 MW Wind / 120 MWh BESS
38 MW Geothermal* / 17 MW Hydro
Installed PV & Wind:
102% of Sys. Peak

Geothermal Plant is in operation at reduced capacity (30 MW) due to volcanic eruption. An 8 MW expansion, to 46 MW, is approved

* 30 MW PV + 120 MWh BESS (Approved)

Renewable Energy Peak Daily Production in 2022
(e.g. occurred on May 22, 2022)
Major Components of VRE Integration

Competitive Procurement

Resource & Integration Planning

IBR Interconnection and Performance Requirements
IBR Interconnection and Performance Requirements

Wärtsilä PV + BESS project – O'ahu, Hawai'i, USA
36 MW PV + 144 MWh BESS
IEEE 1547-2018 – Distributed Energy Resource (DER) Interconnections

Normal performance Categories (B.3.2)
Abnormal performance categories (B.3.3)
Reference point of applicability (§4.2)
Prioritization of DER responses (§4.7)
Entering Service (§4.10)
Voltage-reactive power mode (§5.3.3)
Voltage-active power mode (§5.4.2)
Voltage and Frequency Ride-through (§6.4.2 & §6.5.2)
Rate of Change of Frequency Ride-through (§6.5.2.5)
Frequency-droop (§6.5.2.7)
Voltage flicker limits (§7.2.3)
Harmonics - Current distortion limits (§7.3)
Limitation of Overvoltage (§7.4)
Islanding – Unintentional (§8.1) and Intentional (§8.2)

Each utility adopting the code should review the requirements and default parameters and note any exceptions it needs to take to the requirements or allowable parameter ranges in the SRD. The parameter settings the utility requires are documented in the URP.

IEEE 1547 Requirements
IEEE 1547.1 Test Procedures Performance
UL 1741 Certification Safety & Performance
Local Electrical Code Equipment Installation

Source Requirements Document (SRD) & Utility Required Profile (URP)

Exceptions
Parameter Settings
IEEE 2800-2022 - Transmission Interconnection of Inverter Base Resources (IBRs)

Utilization of these capabilities is outside the purview of 2800

Source: EPRI, 2021
Resource & Integration Planning

Tesla PV + BESS project – Kaua‘i, Hawai‘i, USA
13 MW PV + 52 MWh BESS
Resource and Integration Planning

Representative VRE generation profiles

Distributed PV variability is smoothed by geographic diversity.
Competitive Procurement

Kapolei Energy Storage (Plus Power) – O'ahu, Hawai'i, USA
185 MW / 565 MWh BESS
Potential for higher efficiency and lower costs in generation resource acquisition

Overview
In December 2006, the PUC approved in its Decision and Order No. 23121 (Docket No. 03-0372) the Framework for Competitive Bidding as the required mechanism for acquiring or building new generation capacity in Hawaii.

Competitive Bidding Framework
• Competitive bidding facilitates wholesale market competition, enhances the potential for higher efficiency and lower costs, and provides a level playing field on which all generation options can compete.
• Applies to electric utilities under the PUC’s jurisdiction.

Key Competitive Bidding Framework Elements
• Consistent with Integrated Resource Plan (Power Development Plan)
  • Proposed scope of request for proposals (RFP) is included in the utility’s resource plan.
  • PUC may grant waivers from competitive bidding where:
    • Competitive bidding will unduly hinder the ability to add needed generation in a timely fashion (e.g., in an emergency situation)
    • The utility and its customers will benefit more if the generation resource is owned by the utility
    • More cost-effective or better performing generation resources are likely to be acquired more efficiently through different procurement processes; competitive bidding will impede or create a disincentive for integrated resource planning (IRP), RPS or other government objectives, or conflict with requirements of other controlling laws or regulations
    • A waiver will likely result in lower cost to customers, increased reliability, or is otherwise in the public interest
## Evolution of PPA Payment Structures

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<tr>
<th>As-Available</th>
<th>Take or Pay</th>
<th>Lump Sum</th>
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<tbody>
<tr>
<td>- Utility only pays for energy export</td>
<td>- Utility pays for available energy.</td>
<td>- Most recent structure used to procure utility “dispatched” RE.</td>
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<td>- Accounting is simple.</td>
<td>- Available energy must be calculated during curtailment events or an average energy amount can be agreed to up front.</td>
<td>- Unlocks more grid flexibility and benefits from RE resources.</td>
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<td>- RE project owner bears the risk of curtailment and risk is priced into their energy price.</td>
<td>- Risk is better placed on utility; utility in best position to make grid and operational changes to reduce curtailment risk.</td>
<td>- Decouples payments from the energy production.</td>
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<tr>
<td>- PPA curtailment order is reverse-chronological seniority of PPAs.</td>
<td>- Utility bears the risk of curtailment which reduces the energy price; more bankable.</td>
<td>- Sets target for project operational “availability” &amp; MWh “performance”.</td>
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<tr>
<td>- Curtailment risk estimated with grid modeling and projection of utility operating practices and system changes over PPA term.</td>
<td>- Litigation risk greatly reduced.</td>
<td>- Further reduces developer risk / price.</td>
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<tr>
<td>- Utility bears a significant and increasing risk of litigation over curtailment events and practices.</td>
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Mahalo!
(Thank you)

For more information, contact:

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Established in 1907
Statewide system with 3 universities & 7 community colleges
Over 50,000 students
Manoa is the largest and main research campus
- 14,000 undergraduate students
- 6,000 graduate students

School of Ocean and Earth Science and Technology
is the largest research unit on the Manoa campus
~$100 million extramural funding per year
Hawaii Natural Energy Institute (HNEI)  
University of Hawai‘i at Mānoa

Organized Research Unit in School of Ocean and Earth Science and Technology  
Founded in 1974, established in Hawai‘i statute in 2007 (HRS 304A-1891)

- Conduct RDT&E to accelerate and facilitate the use of resilient alternative energy technologies and reduce Hawaii’s dependence on fossil fuels.
- Diverse staff includes engineers, scientists, lawyers; students and postdoctoral fellows; visiting scholars

**Areas of Interest**
- Grid Integration (GridSTART)
- Policy and Innovation
- Alternative Fuels
- Electrochemical Power Systems
- Renewable Power Generation
- Building Efficiency
- Transportation

**Core Functions**
- State Energy Policy Support
- Research & Development
- Testing and Evaluation
- Analysis
- Workforce Development
Established to develop and test advanced grid architectures, new technologies and methods for effective integration of renewable energy resources, power system optimization and resilience, and enabling policies

• Serves to integrate into the operating power grid other HNEI technology areas: energy efficiency, renewable power generation, biomass and biofuels, fuel cells and hydrogen
• Strong and growing partnerships with Hawai‘i, national and international organizations including Asia-Pacific nations

**Expertise & Focus:**
- Energy Policy and Regulation
- Renewable Energy Grid Integration
- Smart Grid Planning & Technologies
- Power Systems Planning
- RE Resource Procurement
- Power Systems Operation
- Power Systems Engineering and Standards
- Communications Design and Testing
- Project Management and Execution

Lead for many public-private demonstration projects
Mr. Matsuura joined the Hawai‘i Natural Energy Institute (HNEI), University of Hawai‘i at Mānoa, in 2013 as its Senior Smart Grid Program Manager. He is a founding member of HNEI’s GridSTART (Grid System Technologies Advanced Research Team), a team of professionals focused on energy transition enabling policy and regulation, advanced grid architectures, grid modernization technologies, and novel methods to achieve the reliable grid integration of RE resources, power system optimization and energy resilience goals.

Prior to joining HNEI, he was with the Hawaiian Electric Company for 21 years. His career at Hawaiian Electric included positions of leadership in the areas of transmission and distribution (T&D) engineering, T&D standards and technical services, system operation, transmission planning, smart grid planning, and system integration. Marc is a licensed professional electrical engineer in Hawaii. He holds a B.S. in Electrical Engineering and an M.B.A. from the University of Hawai‘i at Mānoa.